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Carribean flamingo (*Phoenicopterus ruber*) kept at the National Zoological
Gardens of South Africa**

Hagen, Katharina ; Espie, Ian ; Lane, Emily P ; Kotze, Antoinette ; Clauss, Marcus ; Codron, Daryl

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ZORA URL: <https://doi.org/10.5167/uzh-96278>

Conference or Workshop Item

Originally published at:

Hagen, Katharina; Espie, Ian; Lane, Emily P; Kotze, Antoinette; Clauss, Marcus; Codron, Daryl (2014). Mortality and diseases in greater flamingo (*Phoenicopterus roseus*) and Carribean flamingo (*Phoenicopterus ruber*) kept at the National Zoological Gardens of South Africa. In: International Conference on Diseases of Zoo and Wild Animals, Warshaw, Poland, 28 May 2014 - 31 May 2014. Leibniz Institute of Zoo and Wildlife Research (IZW) Berlin, 57-64.

MORTALITY AND DISEASES IN GREATER FLAMINGO (*PHOENICOPTERUS ROSEUS*) AND CARIBBEAN FLAMINGO (*PHOENICOPTERUS RUBER*) KEPT AT THE NATIONAL ZOOLOGICAL GARDENS OF SOUTH AFRICA

HAGEN K¹, ESPIE I², LANE EP², KOTZE A², WYSS F¹, CLAUSS M¹, CODRON D^{1,3}

¹University of Zurich, Vetsuisse Faculty, Clinic for Zoo Animals, Exotic Pets and Wildlife, Winterthurerstrasse 260, 8057 Zurich, SWITZERLAND; mclauss@vetclinics.uzh.ch

²National Zoological Gardens of South Africa, 232 Boom St, Pretoria, SOUTH AFRICA

³Florisbad Quaternary Research, National Museum, PO Box 266, Bloemfontein 9300, SOUTH AFRICA

Summary

Flamingos are known for susceptibility to traumatic injuries and other diseases. So far, no species-specific management concepts exist for individual flamingo species. In this study, we demonstrate that although the causes of mortality were similar between a group of *Phoenicopter* *roseus* and a group of *P. ruber* that were kept at the same facility under identical husbandry conditions, mortality was significantly higher in *P. ruber*, which suggests a higher disease susceptibility potentially due to climatic differences between the species natural habitat and those of the zoological institution. *P. ruber* also showed a comparatively high occurrence of haemosiderosis in females, thus confirming one earlier report for flamingos in general. Mortality in *P. roseus* was correlated to population size, suggesting that density-dependent effects were partly responsible for health issues, and that although it is desirable to keep flamingos in large groups, group size must be adjusted to the respective facility.

Introduction

Flamingos (*Phoenicopter* spp.) are very long-lived birds (FOWLER and CUBAS, 2001) and present a variety of health problems in captivity. Trauma is mentioned as one of the most common medical issues in zoos (WYSS and WENKER, 2014). Endoparasites and ectoparasites are also common findings. Infectious diseases reported in flamingos include various viral, bacterial, and fungal pathogens, such as aspergillosis and poxvirus (HUMPHREYS, 1975; TERASAKI et al., 2010). Several diseases are based on nutritional deficiencies, including metabolic bone disease or capture myopathy/vitamin E deficiency (YOUNG, 1967; HUMPHREYS, 1975; FOWLER and CUBAS, 2001). Neoplasia has also been reported (VAN WETTERE et al., 2010). Acute death, most likely related to cardiac failure, can also occur when flamingos are stressed, and has sometimes been linked to atherosclerosis (HUMPHREYS, 1975; WYSS and WENKER, 2014).

NORTON (2005) mentions visceral gout as a pathological finding, but argues that it could possibly be a consequence of dehydration. According to ZSCHIESCHE and JAKOB (1989), *Phoenicopteriformes* show a particularly high incidence of amyloidosis. Haemosiderosis in flamingos is mentioned only as an anecdotal finding, most likely linked to excess dietary iron or vitamin deficiency (DIERENFELD et al., 2005). WADSWORTH et al. (1983) detected haemosiderosis in flamingos and associated it to the length they had spent in captivity. Neither LOWENSTINE and MUNSON (1999) nor KLASING et al. (2012) list flamingos as a susceptible species for haemosiderosis.

In this study, we evaluated necropsy reports for two flamingo species kept at the same facility. The greater flamingo (*Phoenicopter* *roseus*) is native to various parts of Africa, including South Africa, also southern Europe, the Middle East, South and South West Asia (BIRDLIFE, 2014). In contrast, the

habitat of the Caribbean flamingo (*Phoenicopterus ruber*) is mainly found in vicinity of the Caribbean Sea (BIRDLIFE, 2014). The major aim of this study was to test whether differences in the health status and mortality between the two species occurred. Additionally, a similar set of necropsy information was available from a zoological garden of the temperate zone (WYSS and WENKER, 2014).

Material and methods

The two flamingo groups at the National Zoological Gardens Pretoria are housed in two neighbouring enclosures separated by a visitor walkway. Both enclosures measure app. 80 x 45 m, with one side of each enclosure lined by a waterway and a central pool of app. 20 m diameter. Water features have a concrete substrate; the remainder of the enclosure has a grass cover, apart from a clay breeding area of app. 3 m diameter in both enclosures. There were no differences in husbandry between the species. Necropsy reports of greater flamingos and Caribbean flamingos, which died at the National Zoological Garden of South Africa between 1991 and 2013, were evaluated. Necropsies had been performed according to standard protocol. For the greater flamingo there were 91 necropsy reports, including 33 male, 29 female and 29 of unknown gender, with 15 neonates (< 1 month old), 39 juveniles (< 1 year old) and 37 adults. For the Caribbean flamingo there were 121 reports, including in 48 males, 45 females and 28 of unknown gender, with 15 neonates, 30 juveniles and 76 adults.

We used the stocklist, in which all individuals of the greater and the Caribbean flamingo housed in the zoo during that period of time were registered, and also every death, birth, new arrival or departure was listed, to establish population size per year, and also calculated the yearly mortality as the number of animals that died in a year divided by the number of animals ever alive in that year. Relationships between annual population size and annual mortalities were tested by correlation analysis. Differences in the occurrence of specific diseases between certain animal groups were tested by chi-square tests. Parametric or nonparametric tests were used depending on whether data were normally distributed. Statistical analyses were performed in SPSS 21.0 (SPSS Inc., Chicago, IL), with the significance level set to 0.05 (results of up to 0.10 considered as trends).

For comparison, an unpublished evaluation of necropsy reports of greater flamingos from the Zoological Garden of Basel, Switzerland, following the same classification of health problems, is also displayed.

Results and discussion

The distribution of the causes of death at the National Zoological Gardens Pretoria was very similar between both species (figure 1a, b). The most common cause was trauma, followed by infections. Amyloidosis, gout, haemosiderosis, metabolic bone disease and hypercalcaemia were categorised as metabolic diseases and were the third most common cause of death in the Caribbean flamingo. Myopathy, septicaemia, gastrointestinal issues, starvation and heart failure are also noteworthy causes. Drowning, bone deformity, genital tract problems and neoplasia only occurred in one or two cases and therefore were pooled in one group named "other". Considering the three major categories of trauma, infectious diseases and all other deaths, there was no significant difference between the species ($\chi^2 = 2.54$, $P = 0.281$). Comparing the same three categories within greater flamingos between Pretoria and Basle, the difference tended towards significance ($\chi^2 = 5.58$, $P = 0.061$), with more trauma and less infection at Basle (figure 1c). The causes of death and their distribution among individuals reflect what is reported in literature, which confirms that trauma is one of the most frequent causes of death, followed by infections (WYSS and WENKER, 2014). The difference between the two greater flamingo groups could lie in the fact that at the temperate zone institution, animals have to be trans-

ferred to, and kept in, a winter house of limited space (WYSS et al., 2013), which might predispose more for traumatic injuries.

When looking at haemosiderosis, amyloidosis, gout and enteritis, including reports in which one of these findings is mentioned as a health issue, but not necessarily cause of death, the Caribbean flamingo has an occurrence of at least 6 % for each of them (figure 2). The differences between the species were significant for haemosiderosis ($\chi^2 = 3.88$, $P = 0.049$), and tended towards significance for amyloidosis ($\chi^2 = 2.76$, $P = 0.097$), and were not significant for gout ($\chi^2 = 0.64$, $P = 0.423$) and enteritis ($\chi^2 = 1.90$, $P = 0.168$). None of these diseases could be significantly linked to another condition, such as poor body condition, rickets or each other. The high prevalence of amyloidosis and gout was not surprising as both are known to occur frequently in flamingos (NORTON, 2005). Avian amyloid appears to be mainly of the AA-type, which suggests a disease or stress relation (TANAKA et al., 2008). The latter theory was supported by COWAN (1968) who linked amyloidosis to birds more susceptible to stress. It is indisputable however, that the main predisposition can be any chronic inflammation, such as mycobacteriosis for example (COWAN, 1968; LANDMAN et al., 1998). TANAKA et al. (2008) noticed a correlation between pododermatitis, an inflammatory condition, and the occurrence of amyloidosis in mute swans. Since pododermatitis has a very high prevalence in flamingos (NIELSEN et al., 2010; WYSS et al., 2013) this could explain the amyloidosis. In the necropsy reports of this study, foot lesions had not been described in particular, so that it can only be concluded that such lesions probably were not of a magnitude that regularly caught attention. As foot lesions in flamingos depend on the substrate they are kept on (WYSS et al., 2014), the grass enclosures at the facility investigated here might have contributed to a low occurrence and severity; however, NIELSEN et al. (2012) found that grass can also have a negative effect on flamingo foot health. In the literature, lymphoplasmacytic enteritis in flamingos is not mentioned. Haemosiderosis was noted in 10 % of all pathology reports of Caribbean flamingos; in literature, it is mentioned as an anecdotal finding (DIERENFELD et al., 2005), or in an individual case report (BRAYTON, 1992), with only one study reporting a similarly high occurrence as in our study (WADSWORTH et al., 1983). One flamingo in Pretoria even appeared to have died of liver failure due to massive haemosiderosis. In general, haemosiderosis it is thought to be related to an inability to cope with high levels of iron in the diet (KLASING et al., 2012). However, no cause of massive iron intake was found in that flamingo. Other causes for increased iron storage in the liver may include acute phase responses to infection, trauma, or neoplasia (KLASING et al., 2012).

It appeared that in the Caribbean flamingo, females had higher prevalence of several diseases than males (figure 3); while this difference was not significant for amyloidosis ($\chi^2 = 2.07$, $P = 0.149$), gout ($\chi^2 = 0.55$, $P = 0.460$) or enteritis ($\chi^2 = 0.45$, $P = 0.501$), it was significant for haemosiderosis ($\chi^2 = 9.63$, $P = 0.002$). In the species investigated here, male and female contribute equally to breeding so breeding activity per se cannot explain the difference (PERRY, 2005), but a negative calorie balance in females during egg production could be a part of the phenomenon. PUERTA et al. (1989) found that females of *P. ruber chilensis* have a higher erythrocyte number, which in itself should not be linked to haemosiderosis. Anyhow, HAWKEY et al. (1984) and PEINADO et al. (1992) found no significant haematological sex differences in Caribbean flamingos. Nevertheless, the study of WADSWORTH et al. (1983) also suggests, without giving the complete data, that female flamingos are more often affected by haemosiderosis than males.

The average population size over the years was higher in the greater flamingo (190 ± 20) than in the Caribbean flamingo (154 ± 30); this difference was significant (t-test, $P = 0 < 0.001$). Compared over the years, mortality was lower in the greater flamingo (median 1.0 %, range 0 - 9.0 %) than in the Caribbean flamingo (4.0, 0 - 7.0 %, figure 4); this difference was also significant (U-test, $P = 0.005$). While there was no correlation between population size and mortality in the Caribbean flamingo ($\delta = 0.02$, $P = 0.947$, figure 4), there was a significant correlation in the greater flamingo ($\delta = 0.86$, $P < 0.001$, figure 4). When excluding the four years with the highest mortality in the greater flamingo, a significant correlation remained ($\delta = 0.74$, $P < 0.001$), indicating that the effect was not only due to

these four 'outlier' years. When these four years were excluded, the difference in the yearly mortality between the species became even more evident (mortality greater flamingo 0.6 ± 0.7 %, Caribbean flamingo 3.3 ± 1.9 %, t-test, $P < 0.001$). To our knowledge, this is the first report of a species difference in mortality in flamingos, and also the first report of an apparent density-dependent effect on mortality in captivity in this group. As the enclosures of the two species are located directly next to each other, and husbandry and feeding regimes are identical, other reasons than a different predisposition to health problems appear unlikely. It is tempting to assume that this might be due to the difference in the natural habitat, given that the greater flamingo is a native species in South Africa. Therefore, the greater flamingo might be more adapted to the environmental conditions at this zoological institution, whereas the Caribbean flamingo, indigenous in the Caribbean, is not. In Pretoria for example, maximum temperature ranges between 19 and 28 °C, with an average of 21.9°C, and the relative humidity ranges between 48 and 65 %. Cuba, habitat of the Caribbean flamingo, has an average temperature of 30.4°C and a relative humidity between 70 and 80 % (INFORMATION 2014; KLIMATABELLE 2014). This leads to the assumption that habitat requirements differ among flamingo species. Interestingly, this does not translate into evident differences in the causes of death (figure 1), just into a higher general mortality. In other species, such location-related problems are well-known. For example, breeding colonies of Humboldt penguins (*Spheniscus humboldti*) in zoos in the UK have approximately half the chick output of free-living, undisturbed wild colonies, and in these and other penguin species, aspergillosis, an opportunistic fungal infection, is more prevalent in captive than in wild populations (BLAY and CÔTÉ, 2001; ELLENBERG et al., 2006; BUNTING et al., 2009).

Density-dependent effects on morbidity and mortality are well known in free-ranging populations (SINCLAIR, 2003) and production animals (BURGER and KAISER, 1996), but have received comparatively little attention in the literature on zoo animal management (MÜLLER et al., 2013). In the absence of other evident patterns in the diseases of the greater flamingo in this study, the relevance of keeping captive populations below a certain threshold (that may have to be determined empirically) appears important when trying to reduce mortalities. Regularly comparing stock numbers and mortality records thus is an important aspect of the management of animals kept in herds or flocks (MÜLLER et al., 2013).

Conclusion

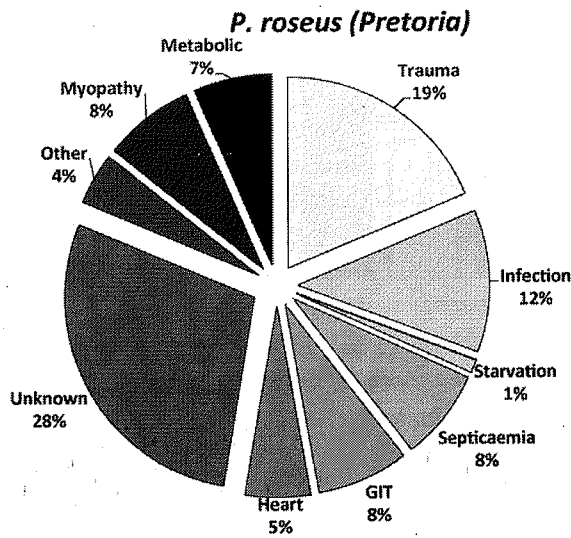
It was confirmed that trauma is the main cause of death in captive flamingos, and management efforts should increase to reduce trauma-related mortality. Regarding haemosiderosis, the high incidence in Caribbean flamingos and the female predisposition cannot be explained by high dietary iron intake. The species related difference in mortality could be explained by dissimilar husbandry requirements, which so far are not mentioned in husbandry guidelines. Therefore, species-specific guidelines, as suggested by KING and BRAČKO (2014), appear warranted. Additionally, the density-dependent effects such as documented here should be taken into account for future husbandry recommendations, especially in connection with current attempts to increase flamingo flock sizes in captivity (KING and BRAČKO, 2014).

Acknowledgements

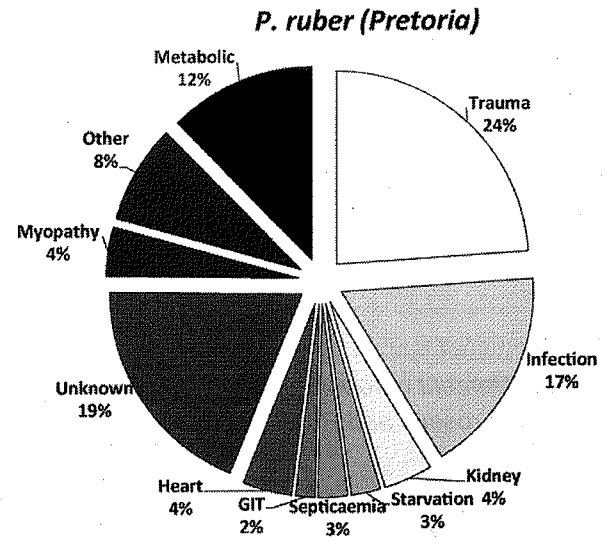
This evaluation was part the Zoo Research Camp (ZRC) 2013 organised and funded by the National Zoological Gardens of Pretoria and the Vetsuisse Faculty of the University of Zurich. We also thank our sponsors for additional support: Alumni Vetsuisse Zürich, Zürcher Universitätsverein, Royal Canin, Schweizerische Vereinigung für Kleintiere, Provect AG, Vereinigung Schweizerischer Futtermittel-

fabrikanten, Eisenhut and Maestrani, and Clifford Nxomani, Adrian Tordiffe, Mark Howitt, Sarah Chabangu for support on site.

a)



b)



c)

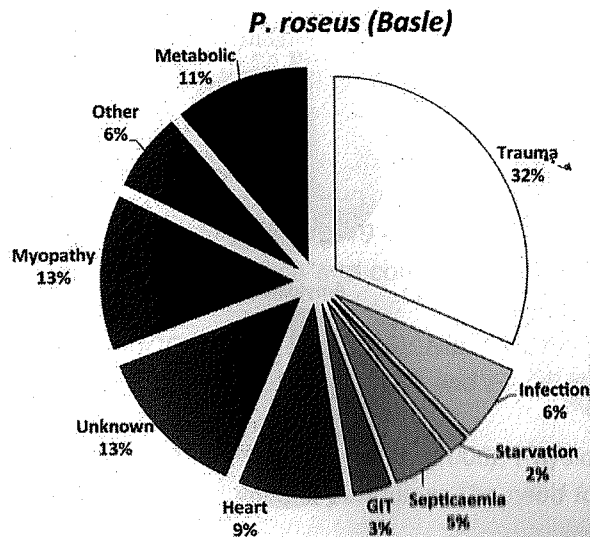


Fig. 1: Causes of death in a) *P. roseus* and b) *P. ruber* at the National Zoological Gardens Pretoria, South Africa and c) *P. roseus* at the Zoological Garden of Basle, Switzerland.

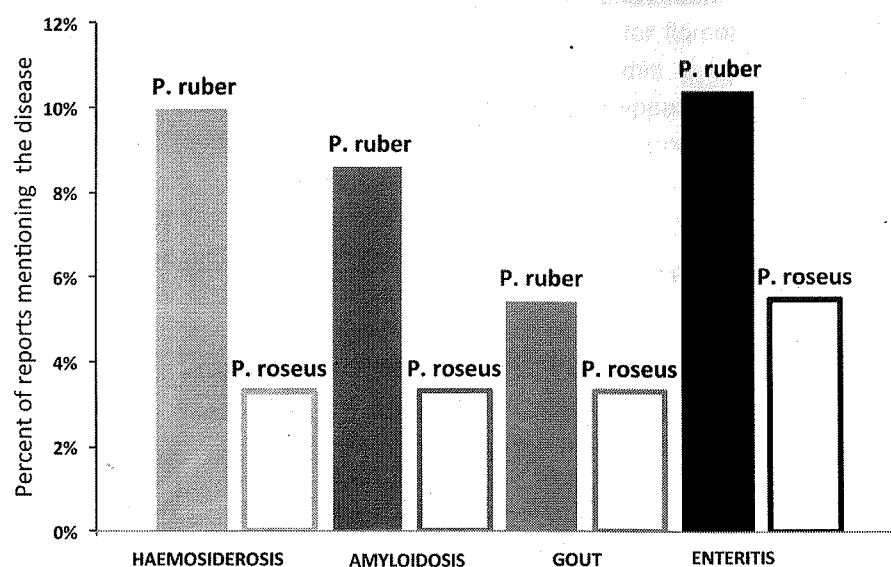


Fig. 2: Percent of reports in which haemosiderosis, amyloidosis, gout and enteritis was mentioned for *P. roseus* and *P. ruber* (of the total number of reports evaluated).

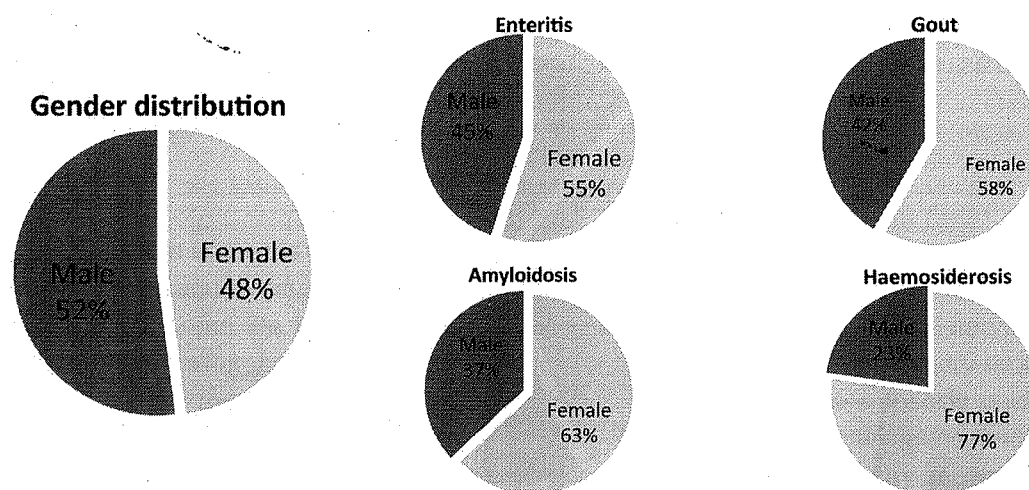
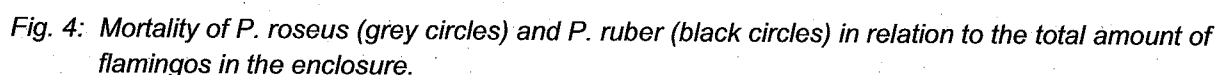


Fig. 3: Comparison of the proportion of males and females in the whole population and among the cases of enteritis ($n = 20$), gout ($n = 12$), amyloidosis ($n = 19$) and haemosiderosis ($n = 22$) in *P. ruber*.



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Leibniz Institute for Zoo and Wildlife Research
(IZW)

Berlin, Germany

&

European Association of Zoo and Wildlife Veterinarians
(EAZWV)

Liebefeld-Berne, Switzerland

**PROCEEDINGS OF THE
INTERNATIONAL CONFERENCE ON
DISEASES OF
ZOO AND WILD ANIMALS
2014**

May 28th – 31st, 2014
Warsaw / Poland

Edited by

Mirjam Grobbel
Anke Schumann

ISSN 1868 - 5846
